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RULES OF THUMB FOR PASSIVE SOLAR HEATING*

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ABSTRACT

Rules of thumb are given for passive solar systems for: 1) sizing solar glazing for 219 cities, 2) sizing thermal storage mass, and 3) building orientation.

1. INTRODUCTION

The LASL Solar Load Ratio method has been used to generate rules of thumb for sizing solar collection area based on monthly weather data for 219 sites in the U.S. and southern Canada. In developing these rules a number of factors have been considered. A principal consideration has been to obtain a high solar savings fraction. However it is also desired that the building not be overglazed so that it will overheat in winter. It is assumed that shading or some other technique can be used to prevent overheating problems in the summer.

In order that the rule of thumb for sizing solar collection area can be given as a ratio of the building floor area, it is necessary to assume a particular level of energy conservation within the building. The values assumed are given in Table I in which the heating load is expressed in terms of a building load coefficient. The values used are slightly tighter than the ASHRAE 90-75 standard.

In order to determine performance, the LASL Solar Load Ratio Method was used. The method has been described in previous LASL papers[1,2] in which correlations for Solar Heating Fraction (SHF) are given as a function of the ratio of monthly solar gain to monthly load. It was found desirable to modify the correlations somewhat in order to make them representative of a Solar Savings Fraction (SSF) instead of the Solar Heating Fraction. These new correlations are given in the Appendix.

The difference between Solar Heating Fraction and Solar [illegible]avings Fraction is discussed in Ref[illegible] 4. The definition of Solar Heatin[illegible]ion used previously is the ratio of [illegible] solar contribution to actual net load. The solar contribution may include energy which does not represent an actual solar savings. By contrast, the Solar Savings Fraction is the ratio of solar savings to a net reference load which is calculated maintaining the building at the desired thermostat set point.

Two key reasons for the switch from SHF to SSF as a design criteria are the following: a) In the design stage the actual load is not known. Therefore it is not possible to predict auxiliary energy uses accurately from a value of SHF. b) In considering the economic merit of the solar design it is appropriate to compare it to a non-solar building. With SSF, the use of a net reference load provides us this basis for comparison. The reader is referred to References 3 and 4 for a more complete discussion.

These new SSF correlations were used together with recently compiled weather data given in Reference 5 to estimate performance. The correlations are based on a reference design described in detail in Reference 4 and a thermostat setting of 65 F in the absence of internal heat. This is approximately equivalent to a thermostat setting of 70-72 F with internal energy generation corresponding to a normal residential application.

Another consideration is that the building not overheat in the winter. The limit used is that the average inside building temperature should not exceed 75 F during January clear-day conditions. This establishes an upper limit for glazing area. The lower limit is taken arbitrarily to be half the upper limit. The purpose of this is simply to give a range of values so that the designer can see the consequence of changing collection area.

A critical decision the designer must face is whether or not to specify insulation covering the glazing at night. Such insulation is very effective, especially in cold climates. In order to see this effect

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the performance estimates are indicated for cases with and without night insulation. The night insulation value used is R9.

2. SOLAR COLLECTION AREA

Rule of Thumb: "A solar collection area of (R1)% to (R2)% of the floor area can be expected to reduce the annual heating load of a building in (location) by (S1)% to (S2)%, or, if R9 night insulation is used, by (S3)% to (S4)%."

where the values of R1, R2, S1, S2, S3, and S4 are selected from Table II for the location of interest. It is recommended that the larger of the two glazing area values given not be exceeded or building overheating can be anticipated on clear winter days.

The rule of thumb is different for each location. An example is the following:

"A solar collection area of 12% to 23% of the floor area can be expected to reduce the fuel consumption of a building in Dodge City, Kansas by 27% to 42%, or, if R9 night insulation is used, by 46% to 73%."

An architect designing a building for Dodge City can use this rule directly to estimate glazing area based on building floor area.

The above is an example for one specific location. Quantitative values can be filled in for other locations from Table II.

Example: A Dodge City building is to have a floor area of roughly 1600 sq ft. Thus the glazed area indicated by the rule of thumb will be in the range of 192 to 368 sq ft but not to exceed 368 sq ft (23%). Within these rough bounds, one can begin schematic design.

The solar savings which would be realized in this example would be approximately as follows:

Glazed Area, sq ft	Solar Savings w/o NI	Solar Savings w/NI
192	27%	46%
368	42%	73%

Discussion. The building in Dodge City is assumed to be designed to an energy conservation standard of 4.6 Btu/degree-day per square foot of floor area (exclusive of the solar glazing). This implies fairly well insulated walls (R-19), double glazing, and moderately low infiltration (3/4 air change per hour (ACH)). Such a rough estimate is sufficient for the schematic design phase. If the builder knows in advance that the design will be to a much different standard, the values can be adjusted proportionally. For example, if the design calls for 9 Btu/DD-ft^2, as might follow from the use R-11 walls and ceiling and 1-1/4 ACH, the values of R_1 and R_2, would be scaled up from 0.12 and 0.23 to 0.18 and 0.35, requiring 50% more south glazing to achieve the same performance.

The south glazing area required does not depend very greatly on the type of passive solar collector to be used (direct gain, Trombe wall, etc.) assuming that thermal storage is adequate so that venting of excess heat would not normally be required during sunny midwinter weather. The exception to this is direct gain, without night insulation, for which the performance can be significantly lower. The values in Table II were derived assuming that the solar glazing is half direct gain and one-half water wall.

The rule of thumb does depend significantly on whether night insulation is to be used. With night insulation, much higher performance is obtained, especially in cold climates.

3. THERMAL STORAGE MASS

Rule of Thumb: "A thermal storage mass of at least 0.6 x SSF pounds of water or 3 x SSF pounds of masonry is recommended for each square foot of south glazing, where SSF is the desired solar savings (in percent). This assumes that the mass is in the direct sun all day as, for example, in a water wall. In direct gain situations this is adequate thermal storage provided, 1) the mass is within the direct gain space or encloses the direct gain space, 2) the mass is not insulated from the space, and 3) the mass has an exposed surface area equal to at least 3 times the glazed area. If masonry is used it is not effective beyond a depth of 4" to 6", measured from the surface. If the mass is located completely out of the sun in back rooms, then about four times as much mass will be needed."

In tabular form this rule is as follows:

Recommended minimum effective thermal storage per sq ft of solar collection area

Expected Solar Savings	pounds of water	pounds of masonry
10%	6	30
20%	12	60
30%	18	90
40%	24	120
50%	30	150
60%	36	180
70%	42	210
80%	48	240
90%	54	270

Discussion. The required amount of thermal storage depends on the fraction of building heat supplied by solar. For small values of solar savings (less than 30%), solar heating contributes principally to offsetting daytime heating requirements and little solar need be or can be stored. In the range between 30% and 70% solar savings, solar heat must be stored from the day through to the night. This diurnal storage is by far the most important consideration in most solar applications. Beyond 70% solar contribution, several-day storage becomes increasingly important and is essential in achieving 100% solar.

Thus the reason that the recommended amount of thermal storage per sq ft of collection area increases with solar fraction is because proportionally more heat must be carried over from the day into the night or into periods of cloudy weather.

4. ORIENTATION

Rule of thumb: "The orientation of the main solar glazing should lie between 20 degrees east and 32 degrees west of true south."

Discussion. If one adheres to this rule of thumb the decrease in performance, compared to an optimum orientation, will nearly always be less than 10% and, more typically, will be less than 6%. The optimum orientation for five sites studied (Albuquerque, Madison, Medford, Boston, and Nashville) varies from 7 degrees east of true south to 15 degrees west of true south. The average for these cities show the optimum to be 6 degrees west of south, with the following decrease in solar savings associated with variations from a true south orientation:

a 5% decrease at 18^{o} east or 30^{o} west
a 10% decrease at 28^{o} east or 40^{o} west
a 20% decrease at 42^{o} east or 54^{o} west

Note that this rule of thumb is based on sensitivity calculations done for Trombe walls and water walls. Some designers prefer to use some direct gain oriented east of true south to "wake up" the building early in the morning. This seems appropriate.

Another important consideration in selecting orientation is summer performance. Summer solar gains are very sensitive to orientation, especially at more southerly latitudes, and east or west orientations are to be avoided as much to prevent summer overheating as to maximize winter performance.

The reason that a slightly westerly orientation is preferred is probably related to the phasing of the load relative to that of the sun. Except for Santa Maria the solar radiation curves are reasonably symmetrical about solar noon. Solar heat received in the afternoon is slightly more effective than that received in the morning. A major part of the heating load of the building occurs during the very late night hours (night setback of the thermostat was not assumed in the calculations). Heat stored in the morning must be saved much longer in order to be effective in satisfying this load; heat stored in the afternoon must be saved a shorter period of time. Another way of looking at it is that solar heat gathered in the morning may simply lead to building overheating in the afternoon whereas heat gathered later in the day is more easily carried over into the night hours.

5. ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of C. Dennis Barley for performing the computer code calculations used to compile Table II, and Robert D. McFarland and William O. Wray for the hour-by-hour calculations and Solar Load Ratio correlations for thermal storage walls and direct gain buildings respectively.

6. REFERENCES

1. J. D. Balcomb and R. D. McFarland, "A Simple Empirical Method for Estimating the Performance of Passive Solar Heated Buildings of the Thermal Storage Wall Type", Proceedings of the 2nd National Passive Solar Conference, Philadelphia, PA, March 16-18, 1978.

2. W. O. Wray, J. D. Balcomb, and R. D. McFarland, "A Semi-Empirical Method for Estimating the Performance of Direct Gain Passive Solar Heated Buildings", Proceedings of the 3rd National Passive Solar Conference, San Jose, CA, Jan. 11-13, 1979.

3. Larry Palmiter, "Development of an Effective Solar Fraction", ISES Silver Jubilee Conference, Atlanta, Georgia, May 28-June 1, 1979.

4. J. D. Balcomb, et al, Passive Solar Design Handbook, Volume II: Passive Solar Design Analysis, U.S. Department of Energy, DOE/CS-0127/2 (Jan. 1980).

5. Cinquemani, Owenby, and Baldwin, "Input Data for Solar Systems", National Climatic Center, Asheville, NC (Nov. 1978).

6. APPENDIX- SOLAR LOAD RATIO CORRELATIONS FOR SOLAR SAVINGS FRACTION

For each month of the heating season, the ratio S/DD is determined, where S is the total monthly solar radiation transmitted through one square foot of south facing, vertical double glazing and DD is the base 65 F heating degree days.

Then the solar saving fraction (SSF) is determined for each month as follows:

$$SSF = 1 - K\,(1-F), \text{ where}$$
$$F = A\,X, \text{ for } X < R$$
$$F = B - C\exp(-DX), \text{ for } X > R$$
$$F \leq 1.000 \text{ for large } X.$$

and where

$$K = 1 + G/LCR$$
$$X = (S/DD)/(LCR \times K)$$

(X is the "Solar Load Ratio"/K)

$$LCR = \frac{\text{building load coefficient, exclusive of solar glazing}}{\text{solar collection area}}$$

(LCR is the "Load Collector Ratio")

Constants for the various passive system types are as follows:

	G	R	A	B	C	D
DG	10.6	0.5	0.5213	1.0133	1.0642	0.6927
DGNI	2.4	0.7	0.542	.9666	1.1479	0.9097
TW	3.6	0.6	0.3693	1.0408	1.0797	0.4607
TWNI	0.5	1.0	0.4556	.9769	1.2159	0.8469
WW	5.0	1.3	0.4025	.9872	1.5053	0.9054
WWNI	0.7	1.2	0.4846	.9799	1.8495	1.2795

These constants were determined from hundreds of month-long hour-by-hour computer simulations for a variety of cities in order to minimize the rms error in predicted annual SSF.

The annual SSF is then obtained from the sums of the monthly values, as follows:

$$\text{Annual SSF} = \frac{\sum_i SSF_i \times DD_i}{\sum_i DD_i}$$

TABLE I

Values of Building Load Coefficient Used in Determining the Solar Glazing Rule of Thumb

Range of Heating Degree-Days	Building Load Coefficient Exclusive of the Solar Wall
less than 1000	7.6
1000 - 3000	6.6
3000 - 5000	5.6
5000 - 7000	4.6
greater than 7000	3.6

The Building Load Coefficient is the additional daily heat which will be required to maintain a one degree Fahrenheit increase in the building inside temperature if the solar collection wall were to be covered with a perfect insulator. For example, if the heat required to maintain the building at 70 F were determined to be 400,000 Btu/day and the heat required to maintain the building at 71 F were determined to be 420,000 Btu/day, then the building load coefficient is equal to the difference or 20,000 Btu/day F.

TABLE II
VALUES TO BE USED IN THE
SOLAR GLAZING RULE OF THUMB

CITY	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BIRMINGHAM, ALABAMA	.09	.18	.22	.47	.44	[illegible]
MOBILE, ALABAMA	[illegible]	.12	.26	.44	[illegible]	[illegible]
MONTGOMERY, ALABAMA	[illegible]	.15	.24	.41	[illegible]	[illegible]
PHOENIX, ARIZONA	.06	.12	[illegible]	[illegible]	[illegible]	[illegible]
PRESCOTT, ARIZONA	.10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TUCSON, ARIZONA	.06	.12	[illegible]	[illegible]	[illegible]	[illegible]
WINSLOW, ARIZONA	.12	.24	[illegible]	.57	[illegible]	[illegible]
YUMA, ARIZONA	.04	.09	[illegible]	[illegible]	[illegible]	[illegible]
FORT SMITH, ARKANSAS	.10	.20	.24	[illegible]	[illegible]	[illegible]
LITTLE ROCK, ARKANSAS	.10	.19	[illegible]	[illegible]	[illegible]	[illegible]
BAKERSFIELD, CALIFORNIA	.08	.15	[illegible]	[illegible]	[illegible]	[illegible]
DAGGETT, CALIFORNIA	.07	.15	[illegible]	[illegible]	[illegible]	[illegible]
FRESNO, CALIFORNIA	.09	.17	[illegible]	[illegible]	[illegible]	[illegible]
LONG BEACH, CALIFORNIA	.05	.10	[illegible]	[illegible]	[illegible]	[illegible]
LOS ANGELES, CALIFORNIA	.05	.09	[illegible]	[illegible]	[illegible]	[illegible]
MOUNT SHASTA, CALIFORNIA	.11	.21	[illegible]	[illegible]	[illegible]	[illegible]
NEEDLES, CALIFORNIA	.06	.12	[illegible]	[illegible]	[illegible]	[illegible]
OAKLAND, CALIFORNIA	.07	.15	[illegible]	[illegible]	[illegible]	[illegible]
RED BLUFF, CALIFORNIA	.09	.18	[illegible]	[illegible]	[illegible]	[illegible]
SACRAMENTO, CALIFORNIA	.09	.18	[illegible]	[illegible]	[illegible]	[illegible]
SAN DIEGO, CALIFORNIA	.04	.09	[illegible]	[illegible]	[illegible]	[illegible]
SAN FRANCISCO, CALIFORNIA	.06	.11	[illegible]	[illegible]	[illegible]	[illegible]
SANTA MARIA, CALIFORNIA	.05	.11	[illegible]	[illegible]	[illegible]	[illegible]
COLORADO SPRINGS, COL.	[illegible]	.24	[illegible]	[illegible]	[illegible]	[illegible]
DENVER, COLORADO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
EAGLE, COLORADO	.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GRAND JUNCTION, COLORADO	.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PUEBLO, COLORADO	.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HARTFORD, CONNECTICUT	.12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WILMINGTON, DELAWARE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
WASHINGTON, DC	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
APALACHICOLA, FLORIDA	.05	.10	[illegible]	[illegible]	[illegible]	[illegible]
DAYTONA BEACH, FLORIDA	.04	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
JACKSONVILLE, FLORIDA	[illegible]	.09	[illegible]	[illegible]	[illegible]	[illegible]
MIAMI, FLORIDA	.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ORLANDO, FLORIDA	.03	.06	[illegible]	[illegible]	[illegible]	[illegible]
TALLAHASSEE, FLORIDA	.05	.11	[illegible]	[illegible]	[illegible]	[illegible]
TAMPA, FLORIDA	[illegible]	.06	[illegible]	[illegible]	[illegible]	[illegible]
WEST PALM BEACH, FLORIDA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ATLANTA, GEORGIA	.08	.17	[illegible]	[illegible]	[illegible]	[illegible]
AUGUSTA, GEORGIA	.08	.16	[illegible]	[illegible]	[illegible]	[illegible]
MACON, GEORGIA	[illegible]	.15	[illegible]	[illegible]	[illegible]	[illegible]
SAVANNAH, GEORGIA	.06	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BOISE, IDAHO	.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
LEWISTON, IDAHO	.15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
POCATELLO, IDAHO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CHICAGO, ILLINOIS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MOLINE, ILLINOIS	.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CITY	R1	R2	S1	S2	S3	S4
SPRINGFIELD, ILLINOIS	.15	.30	19	28	42	67
EVANSVILLE, INDIANA	.14	.27	19	29	37	61
FORT WAYNE, INDIANA	.16	.33	17	17	37	60
INDIANAPOLIS, INDIANA	.14	.28	15	21	37	60
SOUTH BEND, INDIANA	.18	.35	12	15	39	61
BURLINGTON, IOWA	.18	.36	20	27	47	71
DES MOINES, IOWA	.21	.43	19	25	40	75
MASON CITY, IOWA	.22	.41	18	19	56	79
SIOUX CITY, IOWA	.23	.46	20	24	53	76
DODGE CITY, KANSAS	.12	.23	27	42	46	73
GOODLAND, KANSAS	.13	.27	26	39	47	74
TOPEKA, KANSAS	.14	.28	24	35	45	71
WICHITA, KANSAS	.14	.28	26	41	45	72
LEXINGTON, KENTUCKY	.13	.27	17	26	35	58
LOUISVILLE, KENTUCKY	.13	.27	18	27	35	59
BATON ROUGE, LOUISIANA	.06	.12	26	43	34	59
LAKE CHARLES, LOUISIANA	.06	.11	24	41	32	57
NEW ORLEANS, LOUISIANA	.05	.11	27	46	35	61
SHREVEPORT, LOUISIANA	.08	.15	26	43	36	61
CARIBOU, MAINE	.25	.50	- N	R -	53	74
PORTLAND, MAINE	.17	.34	14	17	45	69
BALTIMORE, MARYLAND	.14	.27	19	30	38	62
BOSTON, MASSACHUSETTS	.15	.29	17	25	40	64
ALPENA, MICHIGAN	.21	.42	- N	R -	47	69
DETROIT, MICHIGAN	.17	.34	13	17	39	61
FLINT, MICHIGAN	.15	.31	11	12	40	62
GRAND RAPIDS, MICHIGAN	.19	.38	12	13	39	61
SAULT STE. MARIE, MICH.	.25	.50	- N	R -	50	70
TRAVERSE CITY, MICHIGAN	.18	.36	- N	R -	42	62
DULUTH, MINNESOTA	.25	.50	- N	R -	50	70
INTERNATIONAL FALLS	.25	.50	- N	R -	47	66
MINNEAPOLIS-ST. PAUL	.25	.50	- N	R -	55	76
ROCHESTER, MINNESOTA	.24	.49	- N	R -	54	76
JACKSON, MISSISSIPPI	.08	.15	24	40	34	59
MERIDIAN, MISSISSIPPI	.08	.15	23	39	34	58
COLUMBIA, MISSOURI	.13	.26	20	30	41	66
KANSAS CITY, MISSOURI	.14	.29	22	32	43	66
SAINT LOUIS, MISSOURI	.15	.29	21	33	41	65
SPRINGFIELD, MISSOURI	.13	.26	22	34	40	65
BILLINGS, MONTANA	.16	.32	24	31	51	76
CUT BANK, MONTANA	.24	.49	22	23	62	81
DILLON, MONTANA	.16	.32	24	32	54	77
GLASGOW, MONTANA	.25	.50	- N	R -	65	75
GREAT FALLS, MONTANA	.18	.37	23	28	56	77
HELENA, MONTANA	.20	.33	21	25	55	77
LEWISTOWN, MONTANA	.19	.38	21	25	54	76
MILES CITY, MONTANA	.23	.47	21	21	60	80
MISSOULA, MONTANA	.18	.36	15	16	47	68
GRAND ISLAND, NEBRASKA	.18	.36	24	33	51	76
NORTH OMAHA, NEBRASKA	.20	.40	21	29	51	76
NORTH PLATTE, NEBRASKA	.17	.34	25	36	50	76
SCOTTSBLUFF, NEBRASKA	.16	.31	24	36	49	74
ELKO, NEVADA	.12	.25	27	39	52	76
ELY, NEVADA	.12	.23	27	41	50	77
LAS VEGAS, NEVADA	.09	.18	35	56	48	75
LOVELOCK, NEVADA	.13	.25	32	48	53	78
RENO, NEVADA	.11	.22	31	48	49	76
TONOPAH, NEVADA	.11	.23	31	48	51	77
WINNEMUCCA, NEVADA	.13	.26	28	42	49	75
CONCORD, NEW HAMPSHIRE	.17	.34	13	15	45	68
NEWARK, NEW JERSEY	.13	.25	19	29	39	64
ALBUQUERQUE, NEW MEXICO	.11	.22	29	47	46	71
CLAYTON, NEW MEXICO	.10	.20	28	45	45	71
FARMINGTON, NEW MEXICO	.12	.24	29	45	49	76
LOS ALAMOS, NEW MEXICO	.11	.22	25	40	44	72
ROSWELL, NEW MEXICO	.10	.19	30	49	45	73
TRUTH OR CONSEQUENCES	.09	.17	32	51	46	73
TUCUMCARI, NEW MEXICO	.10	.20	30	48	45	73
ZUNI, NEW MEXICO	.11	.21	27	43	45	73
ALBANY, NEW YORK	.21	.41	13	15	41	66
BINGHAMTON, NEW YORK	.15	.30	- N	R -	35	55
BUFFALO, NEW YORK	.19	.37	- N	R -	36	57
MASSENA, NEW YORK	.25	.50	- N	R -	50	71
NEW YORK (CENTRAL PARK),	.15	.30	16	25	36	59
ROCHESTER, NEW YORK	.18	.37	- N	R -	37	59
SYRACUSE, NEW YORK	.19	.38	- N	R -	37	57
ASHEVILLE, NORTH CAR	.10	.20	21	35	37	61
CAPE HATTERAS	09	.17	24	40	36	60
CHARLOTTE, NORTH CAR	08	.17	23	38	36	60
GREENSBORO, NORTH CAR	.10	.20	23	37	37	63
RALEIGH-DURHAM	.09	.19	22	37	36	61
BISMARCK, NORTH DAKOTA	.25	.50	- N	R -	56	77
FARGO, NORTH DAKOTA	.25	.50	- N	R -	51	72
MINOT, NORTH DAKOTA	.25	.50	- N	R -	52	72
AKRON-CANTON, OHIO	.15	.31	12	16	35	57
CINCINNATI, OHIO	.12	.24	15	21	35	57
CLEVELAND, OHIO	.15	.31	11	14	34	55
COLUMBUS, OHIO	.14	.28	13	18	35	57
DAYTON, OHIO	.14	.28	14	20	36	59
TOLEDO, OHIO	.17	.34	13	17	38	61
YOUNGSTOWN, OHIO	.16	.32	- N	R -	34	54
OKLAHOMA CITY, OKLAHOMA	.11	.22	25	41	41	67
TULSA, OKLAHOMA	.11	.22	24	38	40	65
ASTORIA, OREGON	.09	.19	21	32	37	60
BURNS, OREGON	.13	.25	21	32	47	71
MEDFORD, OREGON	.12	.24	21	32	38	60
NORTH BEND, OREGON	.09	.17	25	42	38	64
PENDLETON, OREGON	.14	.27	22	30	43	64
PORTLAND, OREGON	.11	.26	21	31	38	60
REDMOND, OREGON	.13	.27	26	38	47	71
SALEM, OREGON	.12	.24	21	32	37	59
ALLENTOWN, PENNSYL.	.15	.29	16	24	39	63
ERIE, PENNSYLVANIA	.17	.34	- N	R -	35	55
HARRISBURG, PENNSYL.	.13	.26	17	26	38	62
PHILADELPHIA, PENNSYL.	.15	.29	19	29	38	62
PITTSBURGH, PENNSYL.	.14	.28	12	16	33	55
WILKES-BARRE-SCRANTON	.16	.32	13	18	37	60
PROVIDENCE, RHODE IS	.15	.30	17	24	40	64
CHARLESTON, SOUTH CAR.	.07	.14	25	41	34	59
COLUMBIA, SOUTH CAR	.08	.17	25	41	36	61
GREENVILLE-SPARTANBURG	.08	.17	23	38	36	60
HURON, SOUTH DAKOTA	.25	.50	- N	R -	58	79
PIERRE, SOUTH DAKOTA	.22	.43	21	23	58	80
RAPID CITY, SOUTH DAK.	.15	.30	23	32	51	76
SIOUX FALLS, SOUTH DAK.	.22	.45	18	19	57	79
CHATTANOOGA, TENNESSEE	.09	.19	19	32	33	56
KNOXVILLE, TENNESSEE	.09	.18	20	33	33	56
MEMPHIS, TENNESSEE	.09	.19	22	36	36	60
NASHVILLE, TENNESSEE	.10	.21	19	30	33	55
ABILENE, TEXAS	.09	.18	29	47	41	68
AMARILLO, TEXAS	.11	.22	29	46	45	72
AUSTIN, TEXAS	.06	.13	27	46	37	63
BROWNSVILLE, TEXAS	.03	.06	27	46	32	57
CORPUS CHRISTI, TEXAS	.05	.09	29	49	36	63
DALLAS, TEXAS	.08	.17	27	44	38	64
DEL RIO, TEXAS	.06	.12	30	50	39	66
EL PASO, TEXAS	.09	17	32	53	45	72
FORT WORTH, TEXAS	.09	.17	26	44	38	64
HOUSTON, TEXAS	.06	.11	25	43	34	59
LAREDO, TEXAS	.05	.09	31	52	39	64
LUBBOCK, TEXAS	.09	.19	30	49	44	72
LUFKIN, TEXAS	.07	.14	26	43	35	61
MIDLAND-ODESSA, TEXAS	.09	.18	32	52	44	72
PORT ARTHUR, TEXAS	.06	.11	26	44	34	60
SAN ANGELO, TEXAS	.08	.15	29	48	40	67
SAN ANTONIO, TEXAS	.06	.12	28	48	38	64
SHERMAN, TEXAS	.10	.20	25	41	38	64
WACO, TEXAS	.08	.15	27	45	38	64
WICHITA FALLS, TEXAS	.10	.20	27	45	41	67
BRYCE CANYON, UTAH	.13	.25	26	39	52	78
CEDAR CITY, UTAH	.12	.24	28	43	48	75
SALT LAKE CITY, UTAH	.13	.26	27	39	48	72
BURLINGTON, VERMONT	.22	.43	- N	R -	46	68
NORFOLK, VIRGINIA	.09	.19	23	38	37	62
RICHMOND, VIRGINIA	.11	.22	21	34	37	61
ROANOKE, VIRGINIA	.11	.23	21	34	37	61
OLYMPIA, WASHINGTON	.12	.23	20	29	38	59
SEATTLE-TACOMA, WASH	.11	.22	21	30	39	59
SPOKANE, WASHINGTON	.20	.39	20	24	48	68
YAKIMA, WASHINGTON	.18	.36	24	31	49	70
CHARLESTON, WEST VIRG.	.13	.25	16	24	32	54
HUNTINGTON, WEST VIRG.	.11	.25	17	27	34	57
EAU CLAIRE, WISCONSIN	.25	.50	- N	R -	53	75
GREEN BAY, WISCONSIN	.23	.46	- N	R -	53	75
LA CROSSE, WISCONSIN	.21	.41	- N	R -	52	75
MADISON, WISCONSIN	.20	.40	15	17	51	74
MILWAUKEE, WISCONSIN	.18	.35	15	18	48	71
CASPER, WYOMING	.13	.26	27	39	53	78
CHEYENNE, WYOMING	.11	.21	25	39	47	74
ROCK SPRINGS, WYOMING	.14	.28	25	38	54	79
SHERIDAN, WYOMING	.16	.31	22	30	52	75

CANADA

CITY	R1	R2	S1	S2	S3	S4
EDMONTON, ALBERTA	.25	.50	- N	R -	54	72
SUFFIELD, ALBERTA	.25	.50	28	30	67	85
NANAIMO, BRITISH COL.	.13	.26	26	35	45	66
VANCOUVER, BRITISH COL.	.13	.26	20	28	40	60
WINNIPEG, MANITOBA	.25	.50	- N	R -	54	74
DARTMOUTH, NOVA SCOTIA	.14	.28	17	24	45	70
MOOSONEE, ONTARIO	.25	.50	- N	R -	48	67
OTTAWA, ONTARIO	.25	.50	- N	R -	59	80
TORONTO, ONTARIO	.18	.36	17	21	44	68
NORMANDIN, QUEBEC	.25	.50	- N	R -	54	74

-NR- means Not Recommended

Table originally compiled by C. Dennis Barley in Reference 4.